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**NETWORK COMPONENT PERFORMANCE TESTING**

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**BACKGROUND OF THE INVENTION****Field of the Invention**

5           The present invention is related, in general, to data communications networks. In particular, the present invention is related to performance testing of data communications network components.

**Description of the Related Art**

10           A data communications network is the interconnection of two or more communicating entities by one or more links over which data can be transmitted. The communicating entities and data links in data communications networks can be physical components (e.g.,  
15   two tangible computer systems connected by tangible physical cables), or logical components overlaid onto physical components (e.g., application programs running on two different tangible computer systems communicating with each other over a time division multiplexed  
20   channel). Context is generally used to indicate whether physical or logical components are of interest in any particular discussion.

          Performance testing of data communications network components is concerned with gathering data related to  
25   how the data communications network components perform under various use conditions. The ideal method of

performance testing is to deploy data communications network components in the actual environment (e.g., an active commercial data communications network) in which the components are to be used, and thereafter to test  
5 such deployed components.

Unfortunately, it generally not practicable to test data communications network components in their actual environments of use, for a variety reasons. One reason that performance testing of data communications network components in their actual environments of use is not  
10 practicable is that the owners of such environments (e.g., the owners of networks forming part of the Internet) are generally not willing to give up part of their network capacity for testing. That is, insofar as  
15 performance testing requires control (i.e., the ability to vary) and reproducibility of testing conditions in order to adequately test data communications network components, at least a part of the actual network must be "closed off" to allow the testers to set up and vary  
20 testing parameters. Insofar as most data communications networks generally operate at near capacity, most network owners will not or cannot allow a portion of their networks to be closed for testing. Accordingly, for at least the foregoing reasons it is generally not  
25 practicable to performance test data communications network components in their actual environments of use.

Barring use of the actual environment wherein data communications network components are to be deployed, conventionally it is believed that the next best testing  
30 method involves purchasing the hardware/software expected to be used in the actual network, and thereafter testing the data communications network components with such

purchased hardware/software. Unfortunately, since the physical components (each of which corresponds to a physical machine and/or data link) might range into the thousands, such a method is not generally practicable due to the cost and/or space associated with such actual physical components. In addition, insofar as communications programs will generally be utilized with each physical machine, the time involved in loading such programs also makes such testing methods impracticable (e.g., 5 minutes per loading for 1000 machines would be 5000 minutes or roughly 83.3 hours -- or 2 work weeks of 40 hours -- just to load the programs). In addition to the foregoing, a further impracticability arises from the fact that any time a major test parameter is adjusted, the foregoing processes of program loading must often be reduplicated in that the machines must generally be reconfigured, which again takes a great amount of time. Thus, in those situations where data communications network components to be performance tested are expected to be deployed into networks having a relatively large number of physical and logical connections, testing methods involving purchasing the hardware/software expected to be used in the actual network are generally not practicable.

In light of the foregoing, it is apparent that a need exists in the art for a method and system which provide for the practicable performance testing of data communications network components expected to be deployed in environments having a relatively large number of physical and/or logical data network communication components.

## Summary of the Invention

The inventor named herein has devised method and system which provide for the practicable performance testing of data communications network components expected to be deployed in environment having a relatively large number of physical and/or logical data network communication components. In one embodiment, the method includes but is not limited to coupling one or more modified frame relay sub-interface entities internal to at least one network router with one or more corresponding data link layer entities internal to at least one unit under test. In one embodiment, hardware and software are utilized to effect the foregoing described method. In one embodiment, a system includes but is not limited to one or more modified frame relay sub-interface entities internal to at least one network router coupled with one or more corresponding data link layer entities internal to at least one unit under test. In one embodiment, hardware and software are utilized to effect the foregoing described system.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of this patent application will become apparent in the non-limiting detailed description set forth below.

## DETAILED DESCRIPTION

With reference to the Figures, and in particular with reference now to Figure 1, depicted is data communications network 190 which represents an exemplary environment in which a data communications network component would ideally be performance tested if such were practicable. Shown is unit under test 150 (depicted as a computer system resident within data communications network 190), which is the network node to be tested. Shown is that unit under test 150 is physically connected with computer systems 101, 102, . . . , and 10M (where M is some positive integer greater than 2, and which is meant to show series progression from 101 to 10M (e.g., 101, 102, 103, 104, 105, where M is 5); in practice M is generally in the 1,000s range) via physical data links 101PDL, 102PDL, and 10MPDL (where "PDL" in the reference numerals stands for physical data link; in addition, as used herein, the term "physical data link" is also meant to include non-tangible physical data links, including but not limited to electromagnetic transmission data links (e.g., radio, microwave, and infrared transmission data links)).

Data transmitted over physical data links between computer systems has a tendency to become corrupted. It is customary to employ logical entities, which are known in the art as "data link layer entities," on either side of a physical data link where such data link layer entities ensure that data received over the data link is substantially uncorrupted. Accordingly, depicted is that each physical data link 101PDL, 102PDL, and 10MPDL has an associated pair of data link layer entities which ensure

**BRIEF DESCRIPTION OF THE DRAWINGS**

The present invention may be better understood, and its numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

Figure 1 depicts data communications network 190 which represents an exemplary environment in which a data communications network component would ideally be performance tested if such were practicable.

Figure 2 illustrates that from a viewpoint internal to unit under test 150, the logical components and connections generated by computer systems 101-10M and physical data links 101PDL-10MPDL of Figure 1 do not necessarily have to be associated with computer systems 101-10M and physical data links 101PDL-10MPDL of Figure 1.

Figure 3 depicts that network router 350 and network router 360 in communication over physical data link 340PDL.

Figure 4 depicts unit under test 150 having its associated logical components as were described in relation to Figures 1-2 in communication with modified frame relay sub-interface components of a network router.

Figure 5 shows the scheme of Figure 4 modified such that switching logic 500 is used to "break out" the logical channels respectively associated with data link layer entity 1502DLE-150MDLE and place such logical channels on physical data links 101PDL-10MPDL, which allows testing of unit under test 150 using actual

physical data links such as are likely to be encountered in the field.

Figure 6 depicts aggregation unit 600, which in one embodiment is implemented via a Cisco Systems Model 7513 RSP4 VIP-2-50 switch, which receives as input data link layer entity packets produced by network router 650 and 660.

Figure 7 depicts the scheme of Figure 6 modified such that switching logic 500 is used to "break out" the logical channels respectively associated with data link layer entity 1502DLE-150MDLE and place such logical channels on physical data links 101PDL-10MPDL, which allows testing of unit under test 150 using actual physical data links such as are likely to be encountered in the field.

The use of the same reference symbols in different drawings indicates similar or identical items.

that the data transmitted and received over each physical data link is essentially reliable. That is, data link layer entity 101DLE, resident within computer system 101, works with data link layer entity 1501DLE, resident within unit under test 150, to ensure that data transmitted and received over data link 101PDL is substantially error free; data link layer entity 102DLE, resident within computer system 102, works with data link layer entity 1502DLE, resident within unit under test 150, to ensure that data transmitted and received over data link 102PDL is substantially error free; and data link layer entity 10MDLE, resident within computer system 10M, works with data link layer entity 150MDLE, resident within unit under test 150, to ensure that data transmitted and received over data link 10MPDL is substantially error free.

Delivery of data to appropriate computers within data communications network 190 is handled by network layer entities which handle network addressing and routing decisions. Accordingly, shown is that computer systems 101, 102, . . . , 10M, and unit under test 150, respectively have resident network layer entities 101NLE, 102NLE, . . . , 10MNLE, and 150NLE. As shown in Figure 1, typically network layer entities receive data from their respectively associated data link layer entities.

It is becoming more and more common within the art for users to want data encrypted for security reasons. Because encryption adds redundant bits, one of the most common ways such encryption is done is to encrypt and/or decrypt the messages as closely as possible to the data link layer entities (which means that the redundant bits need be carried only through the data link layer).



Accordingly, illustrated in Figure 1 is that each data link layer entity forming a pair spanning a data link has respectively associated with it a companion decryption-encryption service. For example, each of paired

5 decryption-encryption services 101DES and 1501DES is shown respectively associated with each of paired data link layer entities 101DLE and 1501DLE; each of paired decryption-encryption services 102DES and 1502DES is shown respectively associated with each of paired data  
10 link layer entities 102DLE and 1502DLE; and each of paired decryption-encryption services 10MDES and 150MDES is shown respectively associated with each of paired data link layer entities 10MDLE and 150MDLE.

As noted above, for various reasons it is  
15 impracticable for testing labs to buy upwards of 1000 computer systems, physical data links, and associated software, in order to test unit under test 150. Accordingly, even though the physical environment will be substantially as depicted in Figure 1, in the related art  
20 what has been done in the past is to buy some smaller number of computer systems (e.g.,  $M = 10$ ) and then deploy the system to the field, hoping that the testing results "scale" in accord with engineering calculations drawn on the small actual testing setup.

25 Unfortunately, those skilled in the art will recognize that such scaling does not actually tend to occur. In actuality, it is not uncommon for the actual performance of the unit under test to be grossly off from the predicted scaling. It is therefore apparent that a  
30 need exists for a method and system which will allow the testing of unit under test 150 in such a fashion that the actual operation conditions of unit under test 150 are

approached, but without the necessity of purchasing the upwards of a 1000 , physical data links, and associated software, to stress the unit under test 150.

Referring now to Figure 2, shown is that the inventor has discovered that, when viewed from a viewpoint internal to unit under test 150, the logical components and connections generated by computer systems 101-10M and physical data links 101PDL-10MPDL of Figure 1 do not necessarily have to be associated with computer systems 101-10M and physical data links 101PDL-10MPDL. That is, shown in Figure 2 is a way in which logical components internal to unit under test 150 "see" the logical components and connections generated by computer systems 101-10M and physical data links 101PDL-10MPDL. Notice that logical components and connections generated by computer systems 101-10M and physical data links 101PDL-10MPDL, when observed from a viewpoint internal to unit under test 150, need not really be associated in any way with computer systems 101-10M and physical data links 101PDL-10MPDL which are actually involved in generating such connections.

With reference now to Figure 3, shown are network router 350 and network router 360. Depicted are that network router 350 and network router 360 are in communication over physical data link 340PDL. Illustrated are that network router 350 and network router 360 simultaneously maintain several logical connections between frame relay sub-interface entities 3501FRSI - 350MFRSI and 3601FRSI-360MFRSI, respectively.

Shown in Figure 3 for sake of illustration is that in one embodiment network routers 350 and 360 are

implemented via Cisco Systems Model 7206 NPE300/VXR.  
However, it is to be understood that network routers 350  
and 360 can be implemented utilizing any suitable network  
routers.

5           Those skilled in the art will recognize that network  
routers, such as those depicted in Figure 3, are among  
the highest bandwidth communication system devices  
available. The inventor has discovered that, with only a  
relatively small amount of manipulation well within the  
10 skill of one having ordinary skill in the art, the frame  
relay sub-interface entities can be modified such that  
they can work with the data link layer entities depicted  
in Figure 2. The inventor has discovered that this fact,  
along with his realization that such network routers are  
15 several magnitudes faster typical devices to be deployed  
in networks, will allow unit under test 150 to be tested  
in a fashion closely analogous to real world conditions  
under which unit under test 150 is likely to be deployed.

Referring now to Figure 4, shown is unit under test  
20 150 having associated logical components described and  
discussed in relation to Figures 1-2. Depicted is that  
each data link layer entity 1502DLE-150MDLE respectively  
connects with modified frame relay sub-interface entities  
4501DLE-450MDLE of network router 460 via physical data  
25 link 450PDL. Modified frame relay sub-interface entities  
4501DLE-450MDLE are based on standard frame relay sub-  
interface entities such as frame relay sub-interface  
entities 3501DLE-350MDLE of network router 360 of Figure  
3, which have been adjusted such that the modified frame  
30 relay sub-interface entities respond and function as if  
they were data link layer entities 101DLE-10MDLE shown in  
Figure 2.

Assuming that network router 450 supports an aggregate of roughly M times that of unit under test 150, shown is that network router 450 can be used to stress unit under test 150 "as if" unit under test 150 were connected to M computer systems 101-10M as shown and described in relation to Figure 1. Thus the scheme of Figure 4 allows near-real-world testing of unit under test 150 in a fashion that is much less hardware intensive than the testing scenario depicted and described in relation to Figure 1.

Shown in Figure 4 for sake of illustration is that in one embodiment network router 450 is implemented via Cisco Systems Model 7206 NPE300/VXR with an additional module for hardware IPSEC (IP Security). However, it is to be understood that network routers 450 can be implemented utilizing any suitable network router and any suitable IP security module in hardware or software.

Notice that the scheme of Figure 4 utilizes only one physical data link 450PDL to feed into unit under test 150. It has been discovered by the inventor that the scheme of Figure 4 can be enhanced to give even more realistic testing scenarios.

With reference now to Figure 5, shown is the scheme of Figure 4 modified such that switching logic 500 is used to "break out" the logical channels respectively associated with data link layer entity 1502DLE-150MDLE and place such logical channels on physical data links 101PDL-10MPDL, which allows testing of unit under test 150 using actual physical data links such as are likely to be encountered in the field. Switching logic 500 switches on data link layer headers of data link layer

packets produced by modified frame relay sub-interface entities 4501DLE-450MDLE of network router 460, and can be implemented by any suitable switching device.

Insofar as modern network routers such as network  
5 router 450 can generally typically support up to 3,000  
frame relay sub-interfaces (e.g., a typical  
implementation would utilize 1,250 frame relay sub-  
interfaces for each router 450, with the ability to  
subsequently expand to 3,000 frame relay sub-interfaces),  
10 there will be situations in which the schemes depicted in  
Figures 4 and 5 will not provide enough logical channels  
sufficient to adequately stress unit under test 150. The  
inventor has discovered that in such situations the  
number of logical channels can be increased by using an  
15 aggregation techniques illustrated in Figures 6 and 7

Referring now to Figure 6, shown is aggregation unit  
600, which in one embodiment is implemented via a Cisco  
Systems Model 7513 RSP4 VIP-2-50 switch, which receives  
as input data link layer entity packets produced by  
20 network routers 650 and 660. Depicted is that network  
router 650 has modified (to mimic data link entity) frame  
relay sub-interface entities 6501DLE-650PDLE (where P is  
some integer greater than 1 and less than M), which  
respectively interface with data link layer entities  
25 1501DLE-150PDLE of unit under test 150. Illustrated is  
that network router 660 has modified (to mimic data link  
entity) frame relay sub-interface entities 6601DLE-  
660QDLE (where Q is some integer such that  $P + Q = M$ ),  
which respectively interface with data link layer  
30 entities 150(P+1)DLE-150MDLE of unit under test 150.  
That is, in the aggregate the number of logical channels  
P + Q produced by network routers 650 and 660 add up to

the desire M channels necessary to adequately stress unit under test 150. In one implementation each network router 650 and 660 is configured to produce 1,250 logical channels each, which provides, in the aggregate, 2,500  
5 logical channels.

Shown is that aggregation unit 600 accepts data link layer packets from network routers 650 and 660 and sends them over physical data link 680PDL. Notice that the scheme of Figure 6 can be used to increase the number of  
10 data link layer logical channels until unit under test 150 is stressed to the failure point. It is to be understood that even though only two network routers are shown in Figure 6, the scheme of Figure 6 can be expanded to add more network routers to the point necessary such  
15 that enough logical channels can be produced to stress unit under test 150 to virtually any number of desired logical channels M.

With reference now to Figure 7, shown is the scheme of Figure 6 modified such that switching logic 500 is  
20 used to "break out" the logical channels respectively associated with data link layer entity 1502DLE-150MDLE and place such logical channels on physical data links 101PDL-10MPDL, which is allows testing of unit under test using actual physical data links such as are likely to be  
25 encountered in the field. Switching logic 500 switches on data link layer headers of data link layer packets produced by modified frame relay sub-interface entities 4501DLE-450MDLE of network router 460, and can be implemented by any suitable switching device.

30 The foregoing detailed description has set forth various embodiments of the present invention via the use

of block diagrams, flowcharts, and examples. Insofar as such block diagrams, flowcharts, and examples contain one or more functions and/or operations, it will be understood as notorious by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or any combination thereof. In one embodiment, the present invention may be implemented via Application Specific Integrated Circuits (ASICs). However, those skilled in the art will recognize that the embodiments disclosed herein, in whole or in part, can be equivalently implemented in standard Integrated Circuits, as a computer program running on a computer, as firmware, or as virtually any combination thereof and that designing the circuitry and/or writing the code for the software or firmware would be well within the skill of one of ordinary skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the present invention are capable of being distributed as a program product in a variety of forms, and that an illustrative embodiment of the present invention applies equally regardless of the particular type of signal bearing media used to actually carry out the distribution. Examples of a signal bearing media include but are not limited to the following: recordable type media such as floppy disks, hard disk drives, CD ROMs, digital tape, and transmission type media such as digital and analogue communication links using TDM or IP based communication links (e.g., packet links).

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from this invention and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of this invention. Furthermore, it is to be understood that the invention is solely defined by the appended claims. It will be understood by those within the art that if a specific number of an introduced claim element is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim elements. However, the use of such phrases should not be construed to imply that the introduction of a claim element by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim element to inventions containing only one such element, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an"; the same holds true for the use of definite articles used to introduce claim elements. In addition, even if a specific number of an introduced claim element is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two elements," without other



2224a    2224b    2224c    2224d    2224e    2224f    2224g    2224h    2224i    2224j    2224k    2224l    2224m    2224n    2224o    2224p    2224q    2224r    2224s    2224t    2224u    2224v    2224w    2224x    2224y    2224z    2224aa    2224ab    2224ac    2224ad    2224ae    2224af    2224ag    2224ah    2224ai    2224aj    2224ak    2224al    2224am    2224an    2224ao    2224ap    2224aq    2224ar    2224as    2224at    2224au    2224av    2224aw    2224ax    2224ay    2224az    2224ba    2224bb    2224bc    2224bd    2224be    2224bf    2224bg    2224bh    2224bi    2224bj    2224bk    2224bl    2224bm    2224bn    2224bo    2224bp    2224bq    2224br    2224bs    2224bt    2224bu    2224bv    2224bw    2224bx    2224by    2224bz    2224ca    2224cb    2224cc    2224cd    2224ce    2224cf    2224cg    2224ch    2224ci    2224cj    2224ck    2224cl    2224cm    2224cn    2224co    2224cp    2224cq    2224cr    2224cs    2224ct    2224cu    2224cv    2224cw    2224cx    2224cy 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